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The Challenge of Improvised Explosives

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Energetic materials have been developed for decades, and indeed centuries, with a common set of goals in mind. While performance (as a detonating explosive, a propellant, or a pyrotechnic) has always been key, equally important have been the attributes of safety, stability, and reproducibility. Research and development with those goals has led to the set of energetic materials commonly used today.

In the past few decades, the adoption and use of improvised explosives in attacks by terrorists or third-world parties has led to many questions about these materials, e.g., how they may be made, what threat they pose to the intended target, how to handle them safely, and how to detect them. The unfortunate advent of improvised explosives has opened the door for research into these materials, and there are active programs in many countries. Here I will discuss issues and opportunities facing research into improvised explosives.

For those developing improvised explosives, the desired attributes are somewhat different than those listed above. Improvised explosives may be made from a wide variety of fuels and oxidizers, and the first emphasis is on the availability of raw ingredients and simplicity of manufacture. Handling safety is considered with different criteria in mind, and long-term stability is generally less important. So immediately we are faced with a wide-ranging set of materials rather different than those developed by the energetic materials community. This is the first research opportunity - we are faced with applying our strict set of safety standards and practices, developed over decades of research and accidents, to materials with rather different reaction chemistries and initiation mechanisms. Handling safety and response to thermal and physical stimuli must be carefully studied, and we must recognize the poor long-term stability and rapidly destroy unused samples after a short time.

The threat to the intended target may be complex to analyze. Improvised explosives are often physical mixtures of fuels and oxidizers, and do not follow the standard detonation theories that have been developed with military and commercial explosives. The fuel/oxidizer reaction is often limited in rate by transport of mass and heat, and so improvised explosives may react much more slowly than conventional explosives. This leads to three complications. First, there is generally a significant size effect with improvised explosives – small charges release a much lower fraction of their possible thermochemical energy than very large charges. This means that the damage caused by a large charge cannot simply be extrapolated to consider the threat of a small charge, or vice versa. Second, the slow release of energy means its effect on the target can no longer be considered as an instantaneous release, as is usually the case with detonations of conventional explosives. The effect on the target depends not only on the explosive but on the response of the target as well. Third, slow reactions may lead to incomplete reaction in the detonation, with the opportunity for further energy release by afterburn, the reaction of unreacted ingredients with ambient air. This gives a very slow energy release which is not well understood even for conventional explosives. The next research opportunity lies here – current theoretical and modeling approaches cannot accurately account for the mass- and heat-transfer limited reactions in improvised explosives, and their detonation cannot be accurately modeled to assess their threat. Extension of classical detonation theory to account for slow reactions is needed.

The above issues make the determination of explosive equivalence a daunting challenge for improvised explosives. Beyond the evaluation of thermochemical energy for a given mixture, which can be done with standard thermochemistry approaches, the size of the charge and rate of energy release in the context of the physical response time of the target for which the equivalence is being determined must both be considered. Proper inclusion of these aspects is being studied today, but satisfactory solutions are elusive. In their absence, evaluations of equivalence often consider just thermochemical energy, which may not be an accurate representation. Another research opportunity lies here – the ability to understand the temporal energy release profiles of a range of improvised explosives, apply these energy release profiles to targets of interest, and determine the equivalence for a wide range of improvised explosives.

Detection of improvised explosives is central to their defeat. Because the chemistries of improvised explosives are so varied and so different from conventional explosives, new techniques must be developed for their detection. While work is underway now, the challenge is as vast as the range of possible ingredients. It is unlikely that one detection method will be developed suitable for all improvised explosives, and combinations of techniques will surely be necessary.

Opportunities lie in extending our understanding of conventional explosives to these very unconventional improvised explosives. These range from production to assessment of safety and stability, to evaluation and prediction of their performance in the size and against the target of interest, to detection. Ultimately, development of a predictive understanding of performance and detection will enable rapid response to the ever-evolving suite of improvised explosives.

At the same time, results of such research must be adequately protected. There is an inherent conflict between publishing scientific information and protecting it from adversaries, and this issue is very relevant to the field of improvised explosives. While scientific information should be published, information that will assist terrorists in development and application of improvised explosives must not be published in the open literature where they can gain access to it.

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